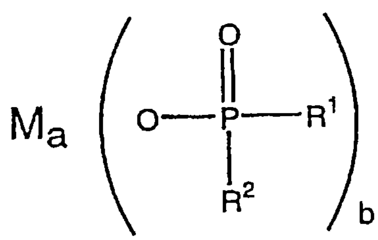
II. REMARKS

As an initial matter, Applicants point out that the Examiner has not yet acknowledged Applicants' foreign priority claim (See Declaration and Power of Attorney for Patent Application, filed October 14, 2004). Applicants respectfully request that the Examiner acknowledge Applicants' foreign priority claim.

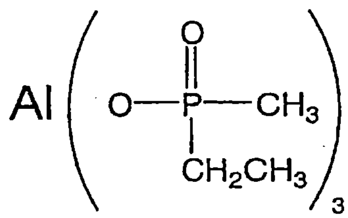
Claim 2 has been amended and new claims 13 to 16 have been added. Specifically, claim 2 has been amended to correct a spelling error and not for a reason related to patentability. The present amendment has no further limiting effect on the scope of claim 2. New claims 13 and 14, respectively, depend upon claims 1 and 9 and further recite "wherein the metal salt of the disubstituted phosphinic acid is represented by formula (I):



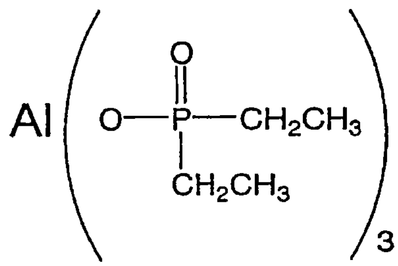
(I)

wherein R^1 and R^2 are each independently an aliphatic hydrocarbon group having 1 to 5 carbon atoms or an aromatic hydrocarbon group; a and b are each an integer of 1 to 9; and M is one metal selected from Li, Na, K, Mg, Ca, Sr, Ba, Al, Ge, Sn, Sb, Bi, Zn, Ti, Zr, Mn, Fe and Ce" as supported on page 5, lines 5-14, of the specification as originally filed.

New claims 15 and 16, respectively, depend upon claims 1 and 9 and further recite that the metal salt of the disubstituted phosphinic acid is selected from the group consisting of (1-1) Aluminum salt of methyl ethyl phosphinate



and (1-2) Aluminum salt of diethyl phosphinate



as supported on page 22, lines 1-7, of the specification as originally filed.

No new matter has been added to the application by the present amendment.

A. <u>The Invention</u>

The present invention pertains broadly to a thermosetting resin composition such as can be used to manufacture printed wiring boards for electronic appliances. In accordance with one present embodiment, a thermosetting resin composition having the features recited in claim 1 is provided. In accordance with another embodiment, a thermosetting resin composition having the features recited in claim 9 is provided. Various other embodiments, in accordance with the present invention, are provided in the dependent claims.

One advantage of the thermosetting resin composition of the present invention is that it has excellent electric characteristics with respect to flame retardancy, heat resistance, moisture resistance and adhesive properties, and it has a relatively low dielectric constant at 1 GHz.

B. The Rejections

Claims 1-4 and 7-11 stand rejected under 35 U.S.C. § 103(a) as unpatentable over Wrezel et al. (U.S. Patent 4,777,227, hereafter the "Wrezel Patent") in view of Kawase et al. (U.S. Patent 3,953,539, hereafter the "Kawase Patent") and Ernst et al. (U.S. Patent 3,046,231, hereafter the "Ernst Patent"). Claim 5 stands rejected under 35 U.S.C. § 103(a) as unpatentable over the Wrezel Patent in view of the Kawase Patent and the Ernst Patent, and further in view of Makino et al. (U.S. Patent 4,128,598, hereafter the "Makino Patent"). Claims 6 and 12 stand rejected under 35 U.S.C. § 103(a) as unpatentable over the Wrezel Patent in view of the Kawase Patent and the Ernst Patent, and further in view of Luttrull (U.S. Patent 6,534,181 B2, hereafter the "Luttrull Patent").

Applicants respectfully traverse the rejection and request reconsideration of the above-captioned application for the following reasons.

C. Applicants' Arguments

A prima facie case of obviousness requires a showing that the scope and content of the prior art teaches each and every element of the claimed invention, and that the prior art provides some teaching, suggestion or motivation to combine the references to produce the claimed invention. In re Oetiker, 24 U.S.P.Q.2d 1443 (Fed. Cir. 1992); In re Vaeck, 20 U.S.P.Q.2d 1438 (Fed. Cir. 1991).

In the present case, the subject matter taught by the references relied upon by the Examiner is insufficient to establish a prima facie case of obviousness because neither the Wrezel Patent, the Kawase Patent, the Ernst Patent, the Makino Patent nor the Luttrull Patent teach, or suggest, "a thermosetting resin composition comprising…a resin having a dielectric constant of 2.9 or less at a frequency of 1 GHz or more" as recited in independent claim 1,

and "a thermosetting resin composition...wherein a dielectric constant of the composition is 3.0 or less at a frequency of 1 GHz or more" as recited in independent claim 9.

i. The Wrezel Patent

The Wrezel Patent teaches "high temperature thermosetting resin compositions" that may be used as a polymer matrix for a printed circuit board, and that include a terpolymer of an ethylenically monosubstituted unsaturated monomer in which the substituent is an aromatic moiety such a styrene, an ethylenically α,β-disubstituted unsaturated monomer in which each substituent is an aromatic or benzylic moiety such as acenaphthylene and a glycidyl ester of a monoethylenically unsaturated acid such as glycidyl methacrylate cross-linked with a copolymer of an anhydride of a dibasic olefinic acid such as maleic anhydride and an ethylenically monosubstituted unsaturated monomer in which the substituent is an aromatic moiety such as styrene (See Abstract).

As admitted by the Examiner, the Wrezel Patent does not teach, or suggest, a "thermosetting resin composition comprising...a metal salt of a disubstituted phosphinic acid" as recited in independent claims 1 and 9 (Office Action, dated April 3, 2006, at 3, lines 24-25). However, this is not the only claim limitation that the Wrezel Patent does not teach. The Wrezel Patent teaches, at col. 8, lines 16-41, a resin that does not include a metal salt of a disubstituted phosphinic acid and that does have a dielectric constant of 2.57 at room temperature, 0% relative humidity, and at 1 mHz. However, the Wrezel Patent does not teach, or even suggest, a "thermosetting resin composition" that includes "a resin having a dielectric constant of 2.9 or less <u>at a frequency of 1 GHz or more</u>" as recited in independent claim 1, and a "thermosetting resin composition...wherein a dielectric constant of the composition is 3.0 or less <u>at a frequency of 1 GHz or more</u>" as recited by independent claim 9.

As is generally known in the art, for time-varying electromagnetic fields, the dielectric constant of materials becomes frequency dependent (See definition of "Dielectric Constant" downloaded from www.en.wikipedia.org/wiki/Dielectric_constant on September 26, 2006, 2 pages, filed herewith). The Wrezel Patent teaches a resin having a dielectric constant of 2.57 at a frequency of only 1 mHz. On the other hand, the frequency range recited by the instant claims is "at a frequency of 1 GHz or more," which is about 100 times greater. There is no teaching in the Wrezel Patent that is even relevant to dielectric constants of a resin material at the much higher frequency range recited by the present claims.

As admitted by the Examiner, the Wrezel Patent also does not teach, or suggest, (i) the monomer of formula (VII) as recited in claim 5, and (ii) an epoxy resin as recited in claims 6 and 12 (Office Action, dated April 3, 2006, at 5, lines 7-8, and at 5, lines 20-21).

ii. <u>The Kawase Patent</u>

The Kawase Patent teaches an "aromatic polyester resin composition having inhibited coloration and method for inhibiting coloration" wherein the aromatic polyester resin composition includes (1) 100 parts, by weight, of an aromatic polyester resin composed mainly of tetramethylene arylcarboxylate units and polymerized by a titanium compound catalyst, (2) 5 to 100 parts, by weight, of a polycarbonate resin, and (3) a coloration inhibiting amount of at least one phosphorous compound (See Abstract). The Kawase Patent teaches that its utilization of the at least one phosphorus compound, which is generally used as a fire-retardant, in the composition is to inhibit an undesirable yellow coloring phenomenon that occurs due to the mixing of tetramethylene aryl dicarboxylate resin with polycarbonate resin (col. 1, line 50, to col. 2, line 11). The Kawase Patent also teaches that the phosphorus compound utilized may be selected from about 85 different compounds, which includes

phosphoric acid, mono- and disubstituted phosphinic acid, and metal salts of phosphinic acid such as sodium an aluminum salts (col. 3, line 30, to col. 4, line 47).

However, the Kawase Patent, which relates to an aromatic polyester resin composition with inhibited coloration that is used for injection or extrusion molding (col. 1, lines 50-57), is completely silent with respect to the dielectric properties of the resin. Therefore, the Kawase Patent does not teach, or even suggest, a "thermosetting resin composition" that includes "a resin having a <u>dielectric constant of 2.9 or less at a frequency of 1 GHz or more</u>" as recited in independent claim 1, and a "thermosetting resin composition...wherein a <u>dielectric constant of the composition is 3.0 or less at a frequency of 1 GHz or more</u>" as recited by independent claim 9.

iii. <u>The Ernst Patent</u>

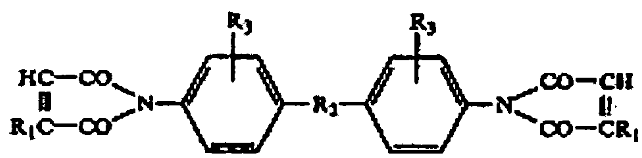
The Ernst Patent teaches "color stabilized n-acyl alkane sulfonic acid salts and methods for production of the same" wherein organic phosphinic acids of the following structure are useful as a discoloration inhibitor in a resin:

where R is an aliphatic, cycloaliphatic, or aryl radical, and where R' represents hydrogen, aryl or aliphatic radical, and M is hydrogen or a salt-forming radical (col. 3, lines 16-27).

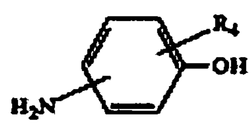
However, the Ernst Patent is completely silent with respect to the dielectric properties of resin. Therefore, the Ernst Patent does not teach, or even suggest, a "thermosetting resin composition" that includes "a resin having a <u>dielectric constant of 2.9 or less at a frequency of 1 GHz or more</u>" as recited in independent claim 1, and a "thermosetting resin composition...wherein a <u>dielectric constant of the composition is 3.0 or less at a frequency of 1 GHz or more</u>" as recited by independent claim 9.

iv. <u>The Makino Patent</u>

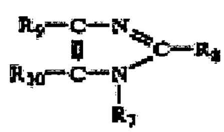
The Makino Patent teaches "thermosetting resin compositions having excellent high temperature characteristics" that are produced by polymerizing together (1) bismaleimide expressed by the general structural formula:



where: R_1 is hydrogen or an alkyl group; R_2 is hydrogen or –O-, $-CH_2-$, $-SO_2$, or –S-S-; and R_1 is hydrogen, alkyl group, or chlorine; (2) aminophenol expressed by the general structural formula:



where R_4 is hydrogen, halogens or alkyl group; (3) a specified epoxy compound; and (4) imidazole that is expressed by the general structural formula:



where R_7 to R_{10} are hydrogen or alkyl group and R_7 and R_8 may be benzyl or phenyl, and which may be added, if necessary (See Abstract). The Makino Patent teaches that the aminophenol (i.e., an amine) is reacted with a maleimide ring of bismaleimide, (col. 3, lines 44-49). On the other hand, in accordance with claim 5 of the present application, the maleimide ring in the monomer unit (f) represented by formula (VII) as defined in claim 5 does not participate in a thermosetting reaction.

The Makino Patent is silent with respect to dielectric constant of its resin composition at 1 GHz. Therefore, the Makino Patent does not teach, or even suggest, a "thermosetting resin composition" that includes "a resin having a <u>dielectric constant of 2.9 or less at a frequency of 1 GHz or more</u>" as recited in independent claim 1, and a "thermosetting resin composition...wherein a <u>dielectric constant of the composition is 3.0 or less at a frequency of 1 GHz or more</u>" as recited by independent claim 9.

v. <u>The Luttrull Patent</u>

The Luttrull Patent teaches "styrene-maleic anhydride copolymer and epoxy resin blend crosslinked with multifunctional amine compounds" wherein the resin blend includes a copolymer of styrene and maleic anhydride, an epoxy resin (brominated, phosphonated, or bromine-free), and a multifunctional amine cross-linking agent (See Abstract). The Luttrull Patent teaches that these resin blends can serve as polymer matrices in composite materials and laminates, and that compared to conventional SMA copolymer/epoxy resin blends Luttrull's resin blends exhibit higher thermal and moisture resistance, and lower dielectric constant and dissipation factor (col. 2, lines 28-37). The Luttrull Patent provides three explicit examples of its blends (col. 4, line 23, to col. 6, line 21), and shows in Table 2 that the dielectric constant of two of its resins at 1 GHz is 4.0 and 3.6, respectively.

As explicitly taught by the Luttrull Patent, its resin blends do not have "a <u>dielectric constant of 2.9 or less at a frequency of 1 GHz or more</u>" as recited in independent claim 1, and "a <u>dielectric constant of the composition is 3.0 or less at a frequency of 1 GHz or more</u>" as recited by independent claim 9.

vi. Summary of the Teachings

Neither the Wrezel Patent, the Kawase Patent, the Ernst Patent, the Makino Patent nor the Luttrell Patent, teach or suggest, a "thermosetting resin composition" that includes "a resin having a dielectric constant of 2.9 or less at a frequency of 1 GHz or more" as recited in independent claim 1, and a "thermosetting resin composition…wherein a dielectric constant of the composition is 3.0 or less at a frequency of 1 GHz or more" as recited by independent claim 9. For this reason alone, the Examiner has failed to establish a prima facie case of obviousness with respect to independent claims 1 and 9 because the documents, either alone or in combination, cannot teach each and every element of the claimed invention.

Applicants remind the Examiner that a proper rejection under Section 103 further requires showing (1) that the prior art would have suggested to a person of ordinary skill in the art that they should make the claimed device or carry out the claimed process, (2) that the prior art would have revealed to a person of ordinary skill in the art that in so making or doing, there would have been a reasonable expectation of success, and (3) both the suggestion and the reasonable expectation of success must be found in the prior art and not in the applicants' disclosure. In re Vaeck, 20 U.S.P.Q.2d 1438, 1442 (Fed. Cir. 1991).

With respect to claim 1, a person of ordinary skill in the art would have no expectation of success of obtaining a "thermosetting resin composition" having "a resin having a dielectric constant of 2.9 or less at a frequency of 1 GHz or more" because none of the Wrezel Patent, the Kawase Patent, the Earnst Patent and the Makino Patent teach such a limitation and the resin taught by the Luttrull Patent has a dielectric constant that explicitly does not meet this limitation.

vii. The Examiner's "Inherency" Argument

The Examiner argues that

> "[a]s to the limitation of dielectric constant of the thermosetting resin composition to be 3.0 or less at a frequency of 1 GHz or more..., in view of the substantially identical thermosetting resin composition disclosed by applicant's and combination of Wrezel et al, Kawase et al, it is examiner's position to believe that the dielectric constant being 3.0 or less is inherently possessed by thermosetting resin compound in the combined prior arts. Because USPTO does not have proper means to conduct experiments, the burden of proof is now shifted to the applicant to prove otherwise." (Office Action, dated April 3, 2006, at 4, line 26, to at 5, line 3).

The Examiner's contention that the combined teachings of the Wrezel Patent and the Kawase Patent would "inherently" possess the limitation of "dielectric constant of the thermosetting resin composition is 3.0 or less at a frequency of 1 GHz" as recited by claims 2 and 9 is flawed because inherency pertains to Section 102 rejections and not to Section 103 rejections.

Inherency applies to anticipation under 35 U.S.C. § 102 when the disclosure of a single reference is sufficient to show that implicit subject matter is the natural result flowing from the teachings, and not merely a probability or a possibility flowing from the teachings. <u>Continental Can Co. USA Inc. v. Monsanto Co.</u>, 20 U.S.P.Q.2d 1746, 1749 (Fed. Cir. 1991). In this case, the Examiner has considered the combined teachings of the Wrezel Patent, the Kawase Patent and the Ernst Patent and opines that the prior art, when viewed as a whole under 35 U.S.C. § 103, "inherently" teaches the subject matter that is missing from each one of these documents. Because inherency applies to Section 102 rejections, and not to Section 103 rejections, the Examiner's argument is untenable as a matter of law.

Furthermore, <u>the Examiner's inherency argument facially ignores the limitation of claim 1, which recites a component "(2) a resin having a dielectric constant of 2.9 or less at a frequency of 1 GHz or more</u>." Because neither the Wrezel Patent, the Kawase Patent, the Ernst Patent, the Makino Patent nor the Luttrull Patent teach this limitation of independent claim 1, no combination of these documents can teach this limitation.

viii. Applicants' Evidence of Non-obviousness

Applicants contend that the Examiner has failed to establish a prima facie case of obviousness against the claimed invention for all of the reasons discussed above. However, even if the Examiner had established a prima facie case of obviousness (which the Examiner has not), the attached "Declaration under 37 CFR 1.132," executed by co-inventor Shinji Tsuchikawa (hereafter, the "Tsuchikawa Declaration"), provides ample evidence of the unobviousness of the presently claimed invention.

With the Tsuchikawa Declaration, Applicants submit experimental data demonstrating that even when disubstituted phosphinic acid, as disclosed by the Kawase Patent or the Ernst Patent, is used in comparative examples in combination with other components of the presently claimed invention, no good result (i.e., dielectric constant exceeded 3.0 at 1 GHz) was obtained as shown in Table 1 on page 7 of the Tsuchikawa Declaration. On the other hand, when a metal salt of a disubstituted phosphinic acid (i.e., component (1) of claim 1) is used in the thermosetting resin composition, then excellent results with respect to dielectric constant (i.e., dielectric constant is less than 3.0 at frequency of 1 GHz or more) are obtained as shown in Tables 1, 2 and 4 on pages 31, 32 and 34 of the original specification of the above-captioned application.

Specifically, a cyanate ester resin was prepared in accordance with Example 1 on page 23, line 25, to page 24, line 5, of the specification as originally filed (See Tsuchikawa Declaration, at 2, line 25, to at 3, line 12). Next, a semi-IPN structure between a copolymer resin comprising styrene and maleic anhydride, and the cyanate resin ester was prepared in accordance with page 24, lines 6-33, of the specification as originally filed (See Tsuchikawa Declaration, at 3, line 13, to at 4, line 6). Subsequently, varnishes were made in accordance with examples described on page 28, lines 1-26, of the specification as originally filed except that, for comparative purposes, various disubstituted phosphinic acids were used in place of

the metal salts of disubstituted phosphinic acid (Tsuchikawa Declaration, at 2, lines 20-24, and at 4, lines 7-19).

In particular, in Table 1 of the Tsuchikawa Declaration, the Comparative flame retardant D used in Comparative Example 7 was methylethylphosphinic acid, and the Comparative flame retardant E used in Comparative Example 8 was diethylphosphinic acid, so as to represent resins of the Ernst Patent (See col. 3, lines 46-56, of the Ernst Patent). In Comparative Example 9 of Table 1 of the Tsuchikawa Declaration, the Comparative flame retardant F was triphenyl phosphine (a phosphorous compound). In Comparative Example 10 of Table 1 of the Tsuchikawa Declaration, the Comparative flame retardant G was triphenyl phosphite (a phosphorous acid). Comparative Examples 9 and 10 represent compositions in accordance with the teachings of the Kawase Patent (See col. 3, line 55, to col. 4, line 14, of the Kawase Patent).

The varnishes thus obtained were then individually applied onto PET film, dried, and solids removed by a cast method followed by pressing of the solids taken out to obtain resin sheets as described on page 28, lines 27-32, of the specification as originally filed (Tsuchikawa Declaration, at 4, lines 25-31). The resin sheets were then evaluated for dielectric constant at 1 GHz using a constant measurement apparatus as described on page 28, line 33, to page 29, line 1, and on page 29, lines 21-27, of the specification as originally filed (Tsuchikawa Declaration, at 4, lines 32-34, and at 5, lines 21-28).

As shown in Table 1 of the Tsuchikawa Declaration, the dielectric constant for Comparative Examples 7 to 10 are, respectively, 3.4, 3.5, 3.3 and 3.3. These comparative test results demonstrate the importance of the metal salt because only when a metal salt of a disubstituted phosphinic acid is employed, in accordance with claims 2 and 9 of the present application, are excellent and unexpected results obtained (i.e. the dielectric constant of the

thermosetting resin composition is "3.0 or less at a frequency of 1 GHz or more") as shown in Tables 1, 2 and 4 on pages 31, 32 and 34 of the present specification.

ix. Applicants' Rebuttal of Examiner's Arguments

The Examiner argues that the thermosetting resin composition taught by the combination of Wrezel and Kawase and Ernst would "inherently possess" a dielectric constant of 3.0 or less at a frequency of 1 GHz or more (Office Action, dated April 3, 2006, at 4, lines 26-30). The Examiner further argues that because the USPTO does not have proper means to conduct experiments, the burden of proof is now shifted to the applicant to prove otherwise, and in support of this argument the Examiner cites In re Best, 195 U.S.P.Q. 430 (C.C.P.A. 1977).

The Examiner's argument is untenable because "inherency" is a doctrine that applies only to a single reference applied under 35 U.S.C. § 102 for the purpose of establishing anticipation. Continental Can Co. USA Inc. v. Monsanto Co., 20 U.S.P.Q.2d at 1749. Inherency does not apply to combinations of references applied under 35 U.S.C. § 103 for the purpose of establishing characteristics of a hypothetical construct such as the Examiner has done. Even in Best, the court points out that inherency applies only to rejections under Section 102. In re Best, 195 U.S.P.Q. 430, 432 (C.C.P.A. 1977)("assertion of inherency under 35 USC 102"). In this case, there are no outstanding Section 102 rejections; therefore, neither inherency nor the court's ruling in Best apply.

Furthermore, the Examiner's contention that Applicants must compare the invention to a hypothetical construct made in accordance with the combined teachings of Wrezel, Kawase and Ernst is flawed because Applicants are only required to compare the invention to the closest prior art. In re Johnson, 223 U.S.P.Q. 1260, 1264 (Fed. Cir. 1984). There is no requirement that Applicant compare the invention to the invention. In re Chapman, 148

U.S.P.Q. 711, 714 (C.C.P.A. 1966). However, Applicants may compare the invention to subject matter that is closer to the invention than the closest prior art. Ex parte Humber, 217 U.S.P.Q. 265, 266 (Bd. Pat. App. & Inter. 1981).

In this case, the Wrezel Patent represents the closest prior art. However, as evident from the Tsuchikawa Declaration, Applicants have compared the subject matter of the presently claimed invention to subject matter that is closer to the claimed invention than the subject matter taught by the Wrezel Patent. Therefore, the comparative evidence provided by the Tsuchikawa Declaration is relevant to demonstrating the unexpected superiority of the presently claimed invention over the teachings of the Wrezel Patent.

The Examiner also contends that the phosphinic acid salt taught by the Ernst Patent is a genus, and that the metal salt of organic phosphinic acid taught by the Kawase Patent is a species so that one of ordinary skill in the art would expect that all species would work well for the genus, motivated by a reasonable expectation of success, and in support of this contention the Examiner cites In re O'Farrell, 7 U.S.P.Q.2d 1673, 1681 (Fed. Cir. 1988).

However, the Examiner has misconstrued the O'Farrell case, which involved inventors who published their own work in a scientific journal and, after their own work became prior art against them, filed for a U.S. patent on a variation of their invention that was suggested in this scientific journal article. In re O'Farrell, 7 U.S.P.Q.2d at1677. The O'Farrell case does not stand for the proposition that a single species in a genus would render obvious the use of other species in the genus for the same purpose as the single species. In fact, the O'Farrell case does not even address this issue. Therefore, the Examiner's reliance on the O'Farrell case and inferences regarding species predictability based on the teachings of the Kawase Patent and the Ernst Patent are erroneous. Consequently, the Examiner has not established a proper motivation to combine the teachings of the Wrezel, Kawase and Ernst patents because there is no reasonable expectation of success.

III. CONCLUSION

The Examiner has failed to establish a prima facie case of obviousness because neither the Wrezel Patent, the Ernst Patent, the Kawase Patent, the Makino Patent nor the Luttrull Patent teach, either alone or in combination, (1) "a thermosetting resin composition comprising...a resin having a dielectric constant of 2.9 or less at a frequency of 1 GHz or more" as recited in independent claim 1, and (2) "a thermosetting resin composition...wherein a dielectric constant of the composition is 3.0 or less at a frequency of 1 GHz or more" as recited in dependent claim 2 and independent claim 9.

Furthermore, even if the Examiner had established a prima facie case of obviousness (which he has not), the comparative evidence submitted by the Tsuchikawa Declaration demonstrates the superior and unexpected dielectric constant at 1 GHz of the present invention over subject matter that is closer to the claimed invention than the closest prior art (i.e., the Wrezel Patent). Thus, even if a prima facie case of obviousness had been established (which it has not) against the instant claims, the evidence of superior and unexpected results provided by the Tsuchikawa is sufficient to overcome it.

For all of the above reasons, claims 1-16 are in condition for allowance and a prompt notice of allowance is earnestly solicited.

Questions are welcomed by the below-signed attorney for applicants.

Respectfully submitted,

GRIFFIN & SZIPL, P.C.

Joerg-Uwe Szipl
Registration No. 31,799

GRIFFIN & SZIPL, P.C.
Suite PH-1
2300 Ninth Street, South
Arlington, VA 22204

Telephone: (703) 979-5700
Facsimile: (703) 979-7429
Email: GandS@szipl.com
Customer No.: 24203

Dielectric constant

From Wikipedia, the free encyclopedia

The **relative dielectric constant** of a material under given conditions is a measure of the extent to which it concentrates electrostatic lines of flux. It is the ratio of the amount of stored electrical energy when a potential is applied, relative to the permittivity of a vacuum. It is also called **relative permittivity**.

Approximate dielectric constants of some materials at room temperature

Material	Dielectric constant
Vacuum	1 (by definition)
Air	1.00054
Polyethylene	2.25
Paper	3.5
Pyrex glass	4.7
Rubber	7
Silicon	11.68
Methanol	30
Water (20°)	80.4
Barium titanate	1200

The dielectric constant is represented as ε_r or sometimes κ or K. It is defined as

$$\varepsilon_r = \frac{\varepsilon_s}{\varepsilon_0}$$

where ε_s is the static permittivity of the material, and ε_0 is vacuum permittivity. Vacuum permittivity is derived from Maxwell's equations by relating the electric field intensity **E** to the electric flux density **D**. In vacuum (free space), the permittivity ε is just ε_0, so the dielectric constant is 1.

Contents

Measurement

The relative dielectric constant ε_r can be measured for static electric fields as follows: first the capacitance of a test capacitor C_0 is measured with air between its plates. Then, using the same capacitor and distance between its plates the capacitance C_x with a dielectric between the plates is measured. The relative dielectric constant can be then calculated as:

$$\varepsilon_r = \frac{C_x}{C_0}$$

For time-varying electromagnetic fields, the dielectric constant of materials becomes frequency dependent and in general is called permittivity.

Practical relevance

The dielectric constant is an essential piece of information when designing capacitors, and in other circumstances

where a material might be expected to introduce capacitance into a circuit. If a material with a high dielectric constant is placed in an electric field, the magnitude of that field will be measurably reduced within the volume of the dielectric. This fact is commonly used to increase the capacitance of a particular capacitor design. The layers beneath etched conductors in Printed Circuit Boards (PCBs) also act as dielectrics.

Dielectrics are used in RF transmission lines. In a coaxial cable, polyethylene can be used between the center conductor and outside shield. It can also be placed inside waveguides to form filters.

Optical fibers are examples of *dielectric waveguides*. They consist of dielectric materials that are purposely doped with impurities so as to control the precise value of ε_r within the cross-section. This controls the refractive index of the material and therefore also the optical modes of transmission. Doped fiber can also be configured to form an optical amplifier.

See also

- Permittivity
- Low-k
- High-k

External links

- Dielectric Constants of common materials (http://www.technick.net/public/code/cp_dpage.php?aiocp_dp=guide_dielectric_constants)

Retrieved from "http://en.wikipedia.org/wiki/Dielectric_constant"

Categories: Electricity | Electric and magnetic fields in matter

---